Blockchain Technology in Agriculture: Enhancing traceability and transparency in the Supply Chain

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In recent years, the agriculture industry has faced numerous challenges in ensuring the traceability and transparency of its supply chain. From food safety concerns to fraudulent practices, the need for a robust system that can provide accurate and reliable information has become increasingly important. This is where blockchain technology comes into play. Blockchain, a decentralized and transparent ledger, has the potential to revolutionize the way we track and verify agricultural products, ensuring trust and accountability throughout the supply chain (Akella *et al.*, 2023).

Blockchain technology, also referred to as distributed ledger technology, is a type of public bookkeeping protocol executed by a network of computing systems. The networked computing systems execute a pre-determined protocol to maintain a record of transactions, which are stored in "blocks." Each block of the blockchain includes data (e.g., one or more records/transactions), a hash value of the immediately preceding block, and a hash value of the contents of the current block. Blockchain is capable of providing immutable data records and traceable transaction history, which provides great potential to enhance efficiency, transparency, and traceability (Tripoli and Schmidhuber, 2018).

Blockchain technology has recently surfaced as a possible solution that might be implemented in food supply chains in order to improve transparency and traceability. Blockchain technology enables full end-to-end transparency and accountability regarding the origin, quality, and distribution of agricultural products (Bai *et al.*, 2019). This is a significant step forward in the industry. The possibility that solutions based on blockchain technology could increase agricultural output, transparency, and long-term viability is an appealing prospect. Farmers, processors, distributors, retailers, and ultimately consumers are all links in the supply chain for global agriculture. Farmers come first in the chain, followed by distributors, then retailers, and finally consumers. Along the whole supply chain, it is critical for there to be complete traceability and transparency of agricultural products (Cai *et al.*, 2019). This is important from both a quality and a sustainability standpoint.

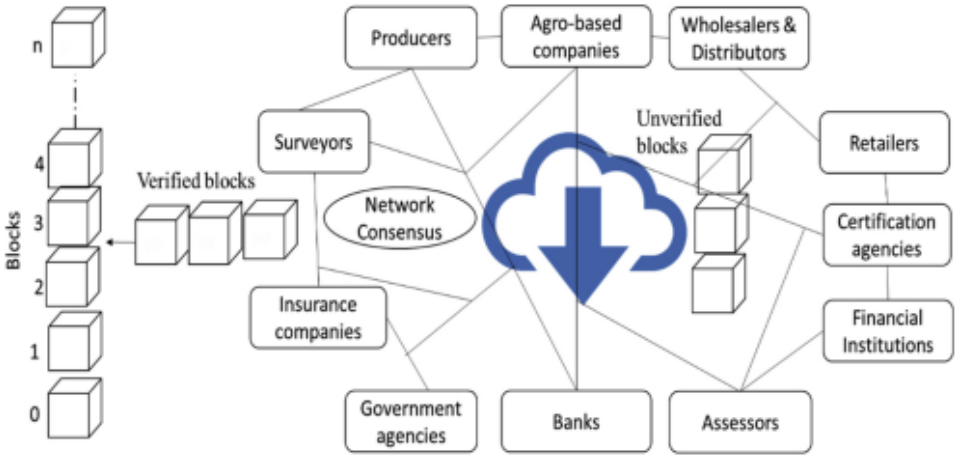

Fig. 1: Blockchain technology in agriculture supply chain (Kamble *et al.*, 2019)

Need for traceability and transparency

The major challenges involved in Agri-food supply chains (AFSCs) include product loss or theft, adulteration, the illegal sale of terminated (or fake) products, illegal labeling, and difficulty in fulfilling customer requirements. Therefore, the traceability system has become a critical component of modern AFSCs (Yao *et al.*, 2022). Information is vital for reducing costs, improving yield and quality (while reducing waste), increasing employees' productivity, and enhancing customer service. It helps to render the supply chain (and its stakeholders) more competitive in the market (Rahman *et al.*, 2021). Traceability, transparency, and auditability are important features that enable one to control (maintain) food quality and

safety and increase customer satisfaction (Feng *et al.*, 2020). Therefore, innovative logistics information systems in AFSCs should effectively provide the abovementioned features.

In modern businesses, market competition is enacted between supply chains rather than individual companies (George *et al.*, 2019). In this regard, real-time information availability, safety, and reliability are highly important for food supply chain efficiency (Zhang *et al.*, 2022). Therefore, an effective traceability system that avoids information islands in the AFSC is becoming an important tool that can help to fulfill the requirement for the integration of blockchain technology (BCT) into traceability systems.

Challenges in the traditional system:

As shown in Figure 2, supply chains have a traditional structure. A central database containing data regarding all processes is created by using this approach. An administrator manages the database. Several limitations apply to this approach. This system uses a server to manage the database. Therefore, if that server fails, the entire system will go down. An administrator who is dishonest could change the data without the stakeholder's knowledge (Mirabelli & solina, 2019). Those manipulations are inadmissible to track back. Thus, this centralized approach is opaque and untraceable as well. Among the major challenges of the traditional supply chain ecosystem are traceability of products, transparency of stakeholders, and trust in collaborative systems. In the traditional approach, there are a lot of intermediaries, causing trust problems and performance problems (Dutta *et al.*, 2020). Various supply chain entities include farmers, distributors, retailers, etc. Consequently, any outbreak involving food products will be extremely difficult to trace (Salah *et al.*, 2019). It is essential to examine the functional impact, social impact, and economic impact of emerging technologies in the supply chain ecosystem. Furthermore, the traditional supply chain ecosystem is highly centralized. This leads to trust issues when multiple organizations collaborate. A centralized process makes it easy to manipulate data without the knowledge of other stakeholders. Any carelessness in the food supply chain may put the lives or health of people at risk. This is a big concern when it comes to traceability. Trust issues within the supply chain can result in significant losses for companies. Companies put the utmost effort into creating trust among consumers. Providing access to data while protecting it from being altered by others should resolve these issues. With blockchain technology, supply chain performance can be improved, and issues can be eliminated. Furthermore, it has some features that make it useful for addressing supply chain concerns beyond its use of distributed ledger technology. As a result of its immutability and distributed nature, it provides a secure and reliable record that cannot be altered or altered. (Ferrag *et al.*, 2020).

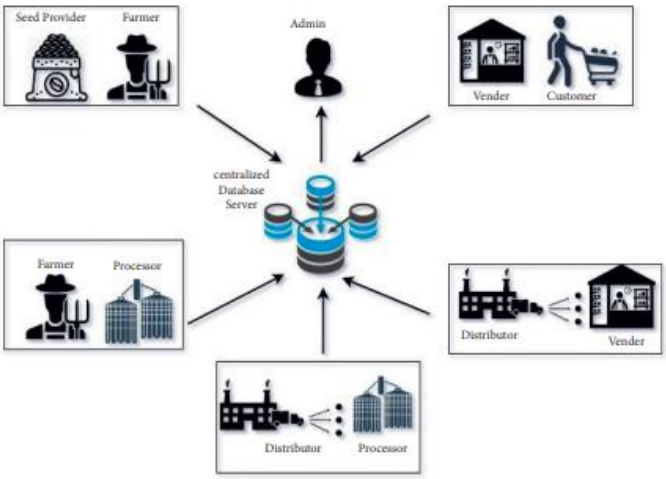

Fig. 2: Traditional supply chain (Ehsan *et al.*, 2022)

How blockchain works:

Blockchain is an immutable and distributed digital ledger containing chained data blocks (Varavallo *et al.*, 2022)(see Figure 3). It is a ledger with a growing list of data records that are validated by the P2P network members/nodes. In blockchain technology (BCT), a chain of data is created by immutably linking a new block with the previous block. Once data have entered the Blockchain, no one can alter them, as an attempt to corrupt the data in one of the blocks will render the following blocks invalid. This property of BCT enables one to tackle data modification problems.

Advantages of blockchain technology in agriculture

- Transparent procurement: The blockchain's distributed ledger can help in the process of procurement. This ledger is shared among all the stakeholders and continuously updated so that each

transaction is visible to all. Companies can easily verify their orders by a distributed ledger.

• Smart contracts for payments: Blockchain's integration with smart contracts automates invoice generation and payment upon task completion, reducing manual processing time and ensuring swift payment settlement.

• No more fraud by rogues: Blockchain's decentralized ledger, updated through consensus among connected nodes, prevents rogue transactions and requires agreement from all stakeholders for execution.

•Provenance tracking: The blockchain-supported solution has a feature of provenance tracking. It means any transaction can be traced back to its time of origin from its current instance (Kouhizadeh *et al .*, 2020).

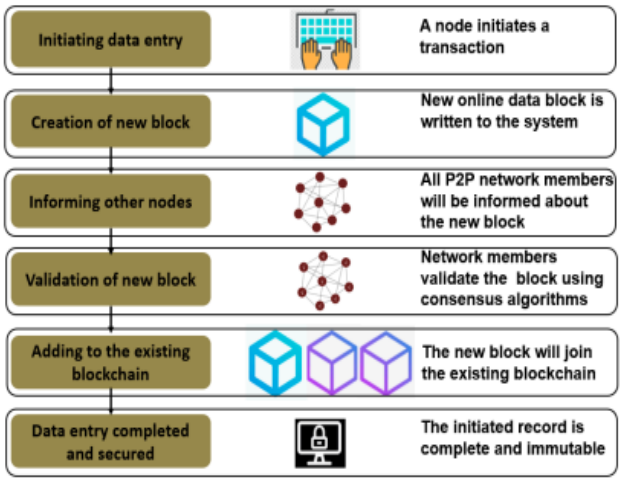

Fig. 3: Blockchain working (Bosona & Gebresenbet, 2023)

Use Cases and Implementation

- Blockchain implemented on a double chain structure helps increase openness and security of transactions, and privacy of enterprise information and can achieve proper resource allocation among all stakeholders in the agriculture sector.
- It also enhances the overall efficiency of the system, eases business expansion, and increases the throughput and credibility of the related platforms (Hasan *et al.,* 2019).
- Blockchain is being used to deal with the trust issues that customers are having in the organic product SCs (Khare and Mittal, 2019).
- Along with efficiency and product tracking, it also helps to maintain a fair relationship between small farmers and big buyers and democratize the supply process (Kshetri, 2019).
- Using blockchain can solve the problem of adulteration and tampering on a large scale by facilitating end-to-end traceability (Behnke and Janssen, 2019).
- A successful application case is on the startup, AgUnity which is safeguarding farmers using blockchain (Helo and Hao, 2019). Another example is Prochain, a new transparent and traceable SC system that has been conceptualized to help cover all the aspects of SC. As food safety is critical to all walks of life, blockchain can directly improve social welfare.

Conclusion

Blockchain technology has the potential to transform the agriculture sector by increasing transparency, traceability, and efficiency in the supply chain. It offers the ability to provide consumers with a clear view of the journey of their food, fostering trust and confidence, while also enabling quick identification and resolution of issues such as contamination or product recalls. Blockchain can reduce fraud, streamline operations, and cut administrative costs by eliminating intermediaries, benefitting both farmers and consumers. It also has the potential to provide financial services to underserved farmers, promote sustainable agricultural practices, and improve data-driven decision-making for precision agriculture. Furthermore, blockchain simplifies international trade and compliance with global regulations, making it easier for agricultural products to access global markets.

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